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DISCUSS THE PHYSIOLOGY OF BALANCE

ANSWER

Balance is the ability to maintain the body's center of mass over its base of support. A properly functioning balance system allows humans to see clearly while moving, identify orientation with respect to gravity, determine direction and speed of movement, and make automatic postural adjustments to maintain posture and stability in various conditions and activities, balance is achieved and maintained by a complex set of sensorimotor control systems that include sensory input from vision (sight),proprioception (touch), and the vestibular system (motion, equilibrium, spatial orientation); integration of that sensory input; and motor output to the eye and body muscles. Injury, disease, certain drugs, or the aging process can affect one or more of these components. In addition to the contribution of sensory information, there may also be psychological factors that impair our sense of balance.

Balance is mediated by the vestibular nuclei in the brain stem

- the labyrinth (a part of the inner ear), is a major organ of our vestibular (balance) system
- the three semicircular canals of the labyrinth is associated with sensing rotary motion
- the brain senses the direction and speed of rotation of the head by the movement of fluid in the semicircular canals.

balance is maintained by the interactions between the labyrinth and other systems in the body, such as the visual and skeletal systems, the main inputs into the balance system are the:

- vestibular labyrinths
- visual system (eyes)
- somatosensory system, especially proprioception

the main outputs from the vestibular nuclei are:

- vestibulo-ocular: permitting reflex eye movements related to posture
- vestibulo-spinal which supply: anti-gravity muscles in the lower limbs reflex arcs which control gait.

The central vestibular system unites the peripheral signals from both ascending pathways to elicit eye, head, and body motor responses for control of balance and orientation.

The vestibular system is a complex set of structures and neural pathways that serves a wide variety of functions that contribute to our sense of proprioception and equilibrium. These functions include the sensation of orientation and acceleration of the head in any direction with associated compensation in eye movement and posture. These reflexes are referred to as the vestibulo-ocular and vestibulospinal reflexes, respectively. The centrally located vestibular system involves neural pathways in the brain that respond to afferent input from the peripheral vestibular system in the inner ear and provide efferent signals that make these reflexes possible. Current data suggest that the vestibular system also plays a role in consciousness, and dysfunctions of the system can cause cognitive deficits related to spatial memory, learning, and navigation.

The vestibular system is one of the key factors in coordinating and maintaining balance. The peripheral apparatus for the vestibular system consists of the semicircular canals, which sense head rotation; and the otoliths, which sense gravity and linear acceleration. The central vestibular pathways form a large network from the vestibular nuclei, ocular motor nuclei, integration centers in the pons and rostral midbrain, vestibulocerebellum, thalamus, to the multisensory vestibular cortex areas in the temporoparietal cortex. The most important structures for the central vestibular pathways are those mediating the vestibulo-ocular reflex (VOR), and the descending pathways into the spinal cord along the medial and lateral vestibulospinal tract which mediate postural control. The cortical structures involved in vestibular function are the parietoinsular vestibular cortex, the retroinsular cortex, the superior temporal gyrus and the inferior parietal lobule. Activation of the cortical network during vestibular stimulation is not symmetrical; dominance is stronger in the nondominant hemisphere, in the hemisphere ipsilateral to the stimulated ear and in the hemisphere ipsilateral to the slow phase of the vestibular caloric nystagmus. Disorder of the vestibular pathway, anyway along its various tracts, may result in balance and coordination impairments and lead to misperception of motion.

There are vast amounts of both afferent and efferent cellular connections involved in the vestibular system. Most of the afferent nerve signals come from the peripheral vestibular system found in the inner ear within the petrous temporal bone. The inner ear contains a bony labyrinth and a membranous labyrinth.

The bony labyrinth is filled with a fluid known as "perilymph" which is comparable to cerebrospinal fluid and drains into the subarachnoid space. Suspended within the bony labyrinth is the membranous labyrinth that contains a fluid known as endolymph unique in composition due to its high potassium ion concentration. Endolymph in the vestibular system is produced by the Vestibular Dark Cells which are similar to the Stria vascularis of the cochlea. Endolymph within the membranous labyrinth surrounds the sensory epithelium and interacts with hair cells within the vestibular apparatus providing the high potassium gradient to facilitate depolarization of the hair cell and afferent nerve transmission.

The vestibular apparatus comprises the utricle, saccule, and superior, posterior, and lateral semicircular ducts. The sensory neuroepithelium in the utricle and saccule is the macula, and the sensory neuroepithelium in the semicircular ducts is the crista ampullaris. Both neuroepithelial structures contain specialized mechanoreceptor cells called "hair cells." Hair cells contain a vast number of cross-linked actin filaments called stereocilia that are connected at the tips by “tip links.” The stereocilia contain cation channels at their apex and are organized in rows by length, with the tallest stereocilium connected to an immobile kinocilium. The kinocilium, the only true cilium, is made of the characteristic 9 + 2 microtubule arrangement.

Hair cells are divided into Type 1 hair cells and Type 2 hair cells.

- Type 1 hair cells have a high variability of resting discharge while
- Type 2 hair cells have a low variability of resting discharge.

Acceleration of endolymph results in the movement of stereocilia, leading to either depolarization or hyperpolarization depending on the direction of the inertial drag. Movement towards the kinocilium causes the interconnected tip links to pull open cation channels resulting in an influx of potassium ions and depolarization. The depolarized hair cell releases glutamate to afferent nerve receptors and neurotransmission to the vestibular ganglion. Movement in the opposite direction to the kinocilium causes stereocilia to converge resulting in tip links closing the cation channels. Lack of potassium influx causes hyperpolarization of the hair cell and inhibition of glutamate release to the afferent nerve.

The vestibular ganglion, also known as Scarpa ganglion, contains thousands of bipolar neurons that receive sensory input from hair cells within the macula and crista ampullaris. Afferent axons from the vestibular ganglion join to become the vestibular nerve. The vestibular nerve then joins the cochlear nerve to become cranial nerve VIII, the vestibulocochlear nerve. Afferent nerve signals carried by the vestibulocochlear nerve are then interpreted by the central vestibular system within the brain. The central vestibular system unites the peripheral signals from both ascending pathways to elicit eye, head, and body motor responses for control of balance and orientation.